

## System for generating sounds

The invention relates to a system for generating sounds with a left front loudspeaker which converts an electric signal of a left audio channel and with a right front loudspeaker which converts an electric signal of a right audio channel, as defined in the preamble of claim 1.

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Such a system for generating sounds in a room is known from WO 99/41947. The electric signals are processed such that spatial rear loudspeakers are dispensed with and the front loudspeakers generate a surround or spatial sound.

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The invention has for its object to improve a surround sound for a listener.

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This object is achieved by means of the characteristics of claim 1. According to the invention, a virtual filter generates virtual sound bodies laterally of a listener in a region between 80 and 100 degrees, preferably between 85 and 95 degrees, more in particular at 90 degrees. Research has shown that the human ear is most sensitive to surrounding sound when sound sources are arranged laterally of a listener's head or when spatial sound is generated laterally of a listener. Since the front loudspeakers are usually positioned close to audio or video devices and are accordingly in front of the listener, two virtual sound bodies are advantageously generated laterally of the listener's head, one virtual sound body for each

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of the two human ears.

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In a simple manner, the filter comprises a sixth-order filter with an infinite pulse response. The sixth-order filter generates a spatial sound at approximately 90 degrees laterally of the head of a listener. For this purpose, the electric signal of an audio channel is applied to the filter, and the pulse response is added to the electric signal of the audio channel again by means of an adder. Two mutually independent sixth-order filters are provided for the signals of the two audio channels.

Advantageously, the virtual filter comprises a second sixth-order filter for signals which are transported from one audio channel to the other. The spatial sound impression is enhanced thereby. The second filter operates with coefficients which are different from the coefficients of the first sixth-order filter.

5           Advantageously, a signal of the corresponding spatial rear channel is added to the signal of an audio channel before it is applied to the filters. The signal of the left rear spatial channel is thus added to the signal of the left audio channel, and the signal of the right rear spatial channel is added to the signal of the right audio channel. The spatial sound impression is enhanced thereby.

10          Advantageously, the signal of the rear spatial channel is low-pass filtered before it is added to the signal of the audio channel. This means that only low frequencies, and no high frequencies, are added to the signal of the audio channel. The lower a frequency, the more difficult it is to determine its origin.

15          Advantageously, the signal of the rear spatial channel is passed through a delay circuit before it is added to the signal of the audio channel. A reverberation or an echo effect is achieved thereby.

An advantageous alternative is that the signal is directly supplied through a reverberation circuit.

20          For a better understanding of the invention, an embodiment will be explained in more detail below with reference to the drawing, in which

Fig. 1 shows five loudspeakers arranged around a listener's head,

Fig. 2 shows a mixer for generating a spatial sound, and

Fig. 3 shows a virtual filter for generating a virtual loudspeaker shifted 25 through 90 degrees.

Fig. 1 shows a listener 1 whose head 2 is surrounded by five real loudspeakers 3, 4, 5, 6, and 7. The left front loudspeaker 3 converts an electric signal of a left audio channel. The right front loudspeaker 4 converts an electric signal of a right audio channel.

30          The left rear surround loudspeaker 5 converts an electric signal of a left rear surround channel, and the right rear surround loudspeaker 6 converts an electric signal of a right rear surround channel. A further, central loudspeaker 7 reproduces an electric signal of a central audio channel. All these five loudspeakers are arranged at an average height which corresponds to the height of the ears of the listener 1. Sound waves and a spatial sound are

generated by means of the real loudspeakers 3 and 4 in a manner as though virtual  
loudspeakers 9 and 10 were present around the listener 1. The listener 1 faces the central  
loudspeaker, thus defining a viewing direction 11. The front loudspeakers 3 and 4 are  
positioned at +30 and -30 degrees with respect to this viewing direction, the rear surround  
5      loudspeakers 5 and 6 at +110 and -110 degrees.

Fig. 2 shows a mixer 15 which is connected between four electrically  
conducting lines 16, 17, 18, and 19 for four audio channels and further lines 20 and 21 for  
audio channels which control a loudspeaker for low frequencies and the centrally arranged  
10     loudspeaker 7. The mixer 15 has a three-stage construction with a first mixer stage 22, a  
second mixer stage 23, and a third mixer stage 24. The first mixer stage 22 comprises a low-  
pass filter 25 and a second low-pass filter 26 as well as a first delay circuit 27 and a second  
delay circuit 28. Alternatively, reverberation units may be provided instead of the delay  
circuits 27, 28. The second stage 23 comprises two adders 29 and 30. The third mixer stage is  
15     formed by a virtual filter 31 and two further adders 32 and 33. The electric signal of the left  
audio channel on the line 16 is supplied to the virtual filter 31 through further lines 34 and  
35. The electric signal of the right audio channel on the line 17 is also supplied to the virtual  
filter 31 through further lines 36 and 37. The signals of the left and right audio channels are  
processed in the virtual filter 31 such that the respective front loudspeakers 3 and 4 generate  
20     sounds as though sound bodies were positioned laterally of the listener in a region between  
80 and 100 degrees, preferably between 85 and 95 degrees, in particular at 90 degrees. These  
sound bodies or sound sources are the virtual loudspeakers 9 and 10. The electric signals thus  
processed are mixed with the electric signals of the left and right audio channels on the lines  
16 and 17 again via the two adders 32 and 33. The signal of the rear left surround channel on  
25     the line 18 and the signal of the rear right surround channel on the line 19 are derived from  
these lines 18 and 19 and are supplied to the two low-pass filters 25 and 26 through further  
lines 38 and 39. High frequencies of above 2500 Hz are filtered out in the low-pass filters 25  
and 26, the frequency being limited by 6 dB per octave starting from 2500 Hz. Each signal is  
individually transported from the low-pass filters 25 and 26 to the respective delay circuits 27  
30     and 28. The electric signal is delayed there. From the delay circuits 27 and 28 the signals thus  
processed are supplied to the adders 29 and 30 via connecting lines 40 and 41 and are mixed  
with the signals coming from the left and right audio channels. The signal of the left audio  
channel is mixed with the signal of the rear left surround channel, and the signal of the right  
audio channel is mixed with the signal of the rear right surround channel. The adders 29 and

30 are adjustable and are capable of adding or mixing the signals in adjustable mixing ratios. Subsequently, the electric signal of the left audio channel, which now comprises components of the signal from the rear left surround channel, reaches the virtual filter 31. Similarly, the signal of the right audio channel 17, which has now been mixed with the signal of the right 5 surround channel, reaches the virtual filter 31. From the virtual filter 31, the processed signals reach the adders 32 and 33 via output lines 42 and 43.

Fig. 3 shows the virtual filter 31, which comprises four filters 50, 51, 52, and 53 of the sixth order, two further delay circuits 54 and 55, and two further adders 56 and 57. 10 The filters 50 and 51 are different from the filters 52 and 53. Such filters are explained in detail in the book "Digitale Signaalbewerking" (Digital Signal Processing) by Ir. A.W.M. van den Enden and Ir. N.A.M Verhoecks, ISBN no. 90 6674 7226, Delta Press B.V., on page 204, section 7.31 entitled "De directe vorm I" (The direct shape I). The signal mixed by the adder 29 from the signals of the left audio channel and the left rear surround channel reaches a first 15 sixth-order filter 50 via the line 35 and is passed on from there through a further connecting line 58 and the adder 56 to the output line 42. The signal of the right audio channel and the right rear surround channel, mixed in the adder 30, is passed on to a second sixth-order filter 51 via the line 37 and reaches the output line 43 via a further connecting line 59 and the adder 57. The signal mixed in the adder 29, furthermore, is mixed with the signal on the line 20 59 via the sixth-order filter 52, the delay circuit 54, and the adder 57. Similarly, the signal mixed in the adder 30 is mixed with the signal on the connecting line 58 by means of the adder 56 via the filter 53 and the delay circuit 55 and is supplied to the output line 42. The signals of the left and right audio channels are mixed with one another crosswise via the filters 52 and 53.

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If digital signals are transmitted, an addition implies a simple summation of two values. All adders are adjustable and are capable of adding the incoming signals in adjustable ratios to one another.

**List of reference numerals**

1	listener
2	head
3	left front loudspeaker
5	right front loudspeaker
4	left surround loudspeaker
6	right surround loudspeaker
7	central loudspeaker
8	central plane
10	left virtual loudspeaker
9	right virtual loudspeaker
11	viewing direction
12	
13	
15	mixer
14	
15	line for left audio channel
16	line for right audio channel
17	line for rear left surround channel
18	line for rear right surround channel
20	audio channel for central loudspeaker
19	audio channel for base loudspeaker
21	first mixer stage
22	second mixer stage
23	third mixer stage
25	low-pass filter
26	low-pass filter
27	delay circuit
28	delay circuit
30	adder
29	adder
31	virtual filter
32	adder

	33	adder
	34	line
	35	line
	36	line
5	37	line
	38	line
	39	line
	40	connecting line
	41	connecting line
10	42	output line
	43	output line
	50	first sixth-order filter
	51	first sixth-order filter
15	52	first sixth-order filter
	53	first sixth-order filter
	54	delay circuit
	55	delay circuit
	56	adder
20	57	adder
	58	connecting line
	59	connecting line